Chapter 7

FINDINGS AND IMPLICATIONS

Over the past several decades, we have learned a great deal about the long-run availability of mineral commodities, thanks in large part to the lively debate among scholars over this important issue. We now know, for example, that the world is not likely to wake up one day to find the cupboard bare or the well dry. We will not run out of mineral commodities the way a car runs out of gasoline. One minute speeding along the highway, the next completely stranded on the berm. Depletion, if it becomes a serious problem, will do so by raising the real costs of finding and producing mineral commodities slowly but persistently over years and decades. Signs of pending scarcity will appear long before serious shortages actually arrive on the scene.

This is because the mineral resources that satisfy the needs of society for materials and energy vary greatly in quality. The high quality, low cost resources currently being exploited account for only a fraction of the total. Once they are gone, large amounts of lower quality resources will remain, which in the absence of offsetting technological change would be more expensive to find and exploit. Long before the lowest quality resources—the last ounce of silver in the earth's crust or the last watt of incoming solar energy—are used, costs would become prohibitive.

So depletion raises the specter of a world where resources are too costly to use rather than a world with no resources. This means that the opportunity cost paradigm rather than the fixed stock paradigm is the appropriate way to assess the long-run availability of mineral commodities. This finding leads to two important corollaries.

First, depletion is no longer inevitable. While over time depletion tends to drive the costs and prices of mineral commodities up, new technology tends to mitigate this tendency. Indeed, mineral commodities can become more available over time if the cost-reducing effects of new technology more than offset the cost-increasing effects of depletion.

Second, measures of availability should reflect the sacrifice that society makes to obtain additional quantities of mineral commodities. Possible indicators of the sacrifice include user costs, production costs, and prices, with prices being the most common measure encountered in part because price data are readily available and in part because prices encompass both user costs and production costs. While these three measures suffer from various shortcomings, and may even at times move in opposite directions, they provide far more useful insights regarding availability trends than fixed stock measures, such as the life expectancies of the reserves or the resource base.

We also now know that new technology has over the past 130 years kept the adverse effects of depletion at bay despite an unprecedented surge in both population and the consumption of mineral commodities. Real production costs and prices for many mineral commodities have actually fallen, implying their availability has increased.

Of course, there have also been shortages. Indeed, shortages have occurred with some regularity for a number of reasons—wars, strikes, economic booms, cartels, insufficient investment in new mines and processing facilities, perverse government policies—but depletion is not among them. This is fortunate, and is why the shortages the world has so far experienced have not for long endured.

Two clouds or caveats, however, cast a shadow this fairly rosy picture. First, we know that the past is not necessarily a good guide to the future. While the current levels and rates of accumulation of mineral reserves augurs well for the next several decades, the more distant future is much harder to discern. We simply do not have the tools to forecast the future course of technological change with any semblance of the accuracy needed to know whether it will suffice to offset the adverse effects of depletion.

Second, our measures of availability take into account only the costs that producers incur and the prices that their customers pay. Environmental and other external costs associated with the production and use of mineral commodities are not considered. At any point in time, this omission imparts a downward bias in our availability measures, causing them to underestimate the true costs and price of mineral commodities.

How it affects trends over time, however, is less clear. The tendency for environmental costs to grow in importance and as a percentage of total costs causes our availability measures increasingly to overestimate availability and to underestimate scarcity. On the other hand, the considerable efforts that governments around the world have made over the past several decades to force companies and consumers to pay for more of what were formerly external costs has partially, perhaps totally, offset this upward bias.

As for the future, some believe that environmental and other social costs may preclude the widespread production and use of mineral commodities. We have seen that this need not be the case, but only if public policy internalizes the external costs, and if society can continue, as it has in the past, to generate the technology needed to keep mineral commodity costs (which would now include all social costs) from rising.

Unfortunately, satisfying both of these two necessary conditions is neither easy nor certain. Recent history suggests that environmental and other social costs, once firms are required to pay them, are just as amenable to the cost-reducing effects of new technology as other costs. However, internalizing these costs may prove far less tractable for two reasons. First, considerable progress is still needed to develop acceptable techniques for measuring the value of the environment, indigenous cultures, and other social goods. This is particularly so for those goods with substantial non-use value, and where different groups within society hold conflicting value systems that lead to greatly different preferences. Second, the political will to force firms to pay for all the social assets they use may falter, in regions where unemployment and poverty are already widespread, and elsewhere as well.

So, despite all that we have learned about the long-run availability of mineral commodities, the central question remains unanswered. We simply do not know whether or not coming generations face a future of mineral commodity shortages. Those who argue otherwise ask the rest of us to share their faith, or lack of faith, in technology. This is why the debate continues.

More geologic information on the incidence and nature of mineral deposits, particularly sub-economic mineral deposits, could be acquired that would go a long way to resolving this critical issue. The needed knowledge, however, is not currently available, nor is it likely to soon become available, largely because little economic incentive exists to learn more about deposits whose profitable exploitation at best lies many years in the future.

Despite this somewhat frustrating state of affairs, important implications still flow from what we do know about the long-run availability of mineral commodities—implications for sustainable development; for green accounting; for indigenous cultures and other social goods; for conservation, recycling, and renewable resource use; and for population, poverty, and discrimination.

Sustainable Development

Sustainable development is a term of many meanings. The World Commission on Environment and Development (1987), better known as the Brundtland Commission after its chair, in its report *Our Common Future*, is widely credited with introducing the term sustainable development into the public lexicon. It defines sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs."

Since then, as Toman (1992) and other writers have noted, many other definitions have surfaced. For some, sustainable development means protecting a particular ecosystem, for others preserving biodiversity, for still others protecting an indigenous culture or a local community from the development of a nearby mine. Then there are those who see sustainable development as helping a mining community remain economically viable after the ore is gone and the mines are closed. In yet another use, sustainable development is the equitable distribution of income, goods, and resources among different countries and people today, and so is void of any intertemporal dimension.

Here we use sustainable development to mean that the present generation behaves in a way that does not preclude future generations from enjoying a standard of living at least comparable to that of our own. This definition is fairly common among economists. Like the original definition of the Brundtland Commission, it has a macro orientation, focusing on changes in the welfare of society as a whole over time rather than the well-being of a particular ecosystem or local community.

Our concern is specifically on the possibility that the current consumption of mineral commodities may force future generations to accept a lower standard of living. Though sustainable development has emerged as a popular concern only over the past decade or two, fears of resource exhaustion as we have seen date back at least to the 18th century writings of Thomas Malthus and the Classical economists. We care about the long-run availability of mineral commodities for many reasons, but the primary reason is presumably the widespread belief that growing scarcity could threaten the welfare of future generations.

Upon some reflection, however, the link between the long-run availability of mineral commodities and sustainable development turns out to be much looser than one might at first suspect. This is because the potential for future generations to enjoy a standard of living equal to that of the present generation depends on all the assets that we pass on. Abundant low-cost mineral resources are just one of these assets. Others include man-made capital (houses, factories, schools, office buildings, roads, bridges, and other infrastructure), human capital (a healthy and well-educated populace), natural capital (a clean environment, pristine wilderness, and rich biodiversity), political and social institutions (stable and democratic government, a well-developed legal system, a tradition of resolving conflict by peaceful means), culture (music, art, dance, theater), and of course technology.

As a result, increasing the availability of mineral commodities may make sustainable development somewhat easier to achieve, but certainly does not ensure it. A generation that fails to invest in new technology, that despoils the environment, and that perpetuates widespread poverty in order to husband its stock of mineral resources for future use is not likely to achieve sustainable development, and is even less likely to earn the gratitude of future generations.

On the other hand, sustainable development is possible even with declining long-run availability of mineral commodities. This simply requires an offsetting increase in the other assets passed on to future generations. Indeed, future generations may even benefit from an increase in the current exploitation of mineral commodities where this allows today’s generation to spend more on infrastructure, education, research and development, and other types of investments.

Going one (big) step further, some economists (Solow 1974, Hartwick 1977, Dasgupta and Heal 1979) have argued that sustainable development is even possible with the complete exhaustion of nonrenewable mineral commodities, using models with strong substitutability assumptions. These assumptions allow the substitution of other inputs for nonrenewable mineral resources in the production of all critical goods. Models with weak substitutability assumptions, which allow for some substitution but not the complete elimination of mineral commodities in the production of goods and services, not surprisingly find the complete exhaustion of mineral resources incompatible with sustainable development. Advocates of the latter set of models (Daly 1996, Ruth 1995, Neumayer 2000) argue with some persuasion that the strong substitutability assumption defies the laws of nature.

However, the debate over strong and weak substitutability, while of some intellectual interest, may be of questionable practical relevance. As pointed out earlier, physical exhaustion is not the issue. We will not literally run out of resources. Scarcity may push the costs of some mineral commodities sufficiently high to preclude their widespread use, but resources will remain in the ground, and so will be available at some price.

In any case, the pace of mineral extraction appears at best to be but a modest determinant of sustainable development. Much more important is how much the current generation spends of its available income on its own consumption and how much it invests.[1] Over the past century the production of mineral commodities has exploded, yet their long-run availability has increased thanks largely to the investment in research and development that has generated a continuing flow of new technologies. This investment coupled with society's other investments has left each succeeding generation better off than that of its parents, at least in developed countries.

This raises two intriguing issues. First, though sustainable development has become the holy grail by which much public policy and behavior is currently judged, is it perhaps too modest a goal? Do we not want the generation of our children and grandchildren to be substantially better off than we are, just as our generation is

[1] Of course, how much it squanders on needless mismanagement, corruption, wars, and other welfare-reducing activities also matter.

substantially better than those of our parents and grandparents? Have we perhaps set our sights too low?

Second, how much should the present generation be saving and how much should it be investing? While it is easy to point to instances of profligate consumption by others, particularly by those richer than we, poverty is also widespread. A large portion of the world's current population does not have adequate food, housing, medical care, or education. How do we in deciding how much of our current income to invest for future generations weigh and compare intergenerational and intra-generational equity? The issue is further complicated by the fact that providing food, housing, medical care, and education to today's poor is also an investment in the future. We will return to this important issue when examining the implications of resource availability for population.

Green Accounting

Among the great economic inventions of the 20th century are modern national income and product accounts. Income accounts, such as the well-known gross domestic product (GDP), measure the total income and output of a nation over a year or some other period. Asset accounts indicate the assets, liabilities, and net worth of a nation at a particular point in time.

National income and product accounts provide a useful report card on a country's economic performance. Is output growing? Is the ratio of investment to consumption rising or falling? How does this ratio compare with that of other countries? Are the country's total assets growing? Are some regions expanding faster than others? How is total income divided between labor, capital, and other resource owners? Such information is of intrinsic interest, and invaluable for the formation of public policy.

National income and product accounts do, however, suffer from a number of deficiencies. With a few exceptions, for example, they have traditionally considered as income and output only sales and purchases that occur in the marketplace. They thus take account of the services provided by a paid maid or housekeeper, but not the services of an unpaid housespouse.

Another important shortcoming concerns their treatment of natural resources and the environment. They currently take into account the production of mineral commodities and their flows through the economy, but completely ignore changes in the stocks of mineral assets in the ground. So while the accumulation and depreciation of physical assets, such as plant and equipment are counted, the discovery of new mineral reserves and their depletion over time are overlooked. This anomaly is troubling since mineral resources are often important inputs into the production of goods and services, just like labor and capital. The treatment of environmental assets is even more of a problem. Not only are changes in these important assets ignored in the asset accounts, they are largely overlooked in the income and product accounts as well.

These shortcomings mean that a country could be enjoying strong apparent economic growth based on the exploitation of its natural resources and environmental assets, which was unsustainable and actually impoverishing the country. A full reckoning of the costs and benefits would reflect a country not growing stronger economically, but rather living off its natural resource and environmental assets.

Green accounting encompasses the efforts over the past several decades in the United States and abroad to augment the traditional treatment of the environment and natural resources in national income and product accounts. In the case of mineral resources, these efforts have produced various procedures for estimating the value of reserves in the ground. These techniques, described in some detail in Nordhaus and Kokkelenberg (1999, ch. 3), attempt in various ways to estimate the value of the user costs (or Hotelling rent) plus the Ricardian rent associated with existing reserves, as illustrated in Figure 3.2.

These efforts indicate that U.S. mineral wealth has changed little over the past several decades. This means that the value of reserve additions plus any revaluation of reserves due to price changes have more or less offset the value of reserve depletions over time. This provides little support for the view that the country is in the midst of an unsustainable mineral resource consumption binge, though several decades is perhaps too short a period of time for assessing this proposition.

Another interesting result flowing from this work concerns the relatively modest contribution of mineral resources to the total wealth of the United States. The value of U.S. mineral resources are estimated at but three to seven percent of the country's tangible capital stock (Nordhaus and Kokkelenberg 1999, p. 104). Adding in other assets, such as human capital, would further reduce these figures.

Even of more interest is the somewhat perverse relationship between a country's mineral wealth and the long-run availability of mineral commodities. While logic would suggest that an increase in mineral availability should tend to increase mineral wealth, this is rarely the case. Again, referring back to Figure 3.2, we can see that an increase in a mineral commodity's price, a sign of growing mineral commodity scarcity, increases the Ricardian rents associated with existing reserves, and hence the value of mineral reserves in the ground.

Alternatively, consider the impact of a new technological development that made it possible to capture BTUs from solar energy more cheaply than from mining and burning coal. The costs of BTU production, which previously might be reflected by the step function in Figure 3.2, would now be replaced by a horizontal line located below the costs of the lowest-cost coal mine. Coal deposits would no longer have any value, and solar energy would enjoy neither Ricardian rents nor user costs (Hotelling rents) since the available supply would have a common cost of production and would be limitless for all practical purposes. While greatly improving the long-run availability of energy, this dramatic development would completely wipe out the mineral wealth once enjoyed by the owners of coal deposits. Nor would this loss be offset by new mineral wealth since the new source of energy, solar power, would create neither Ricardian rents nor user costs.

Perhaps a more realistic example concerns the discovery and development of high grade, low-cost copper deposits in Chile over the past couple of decades. By keeping the world price of copper below what it otherwise would have been, these new mines have reduced the value of copper reserves in the United States and elsewhere. While the increased value of the reserves in Chile may or may not have offset the losses elsewhere, the new mines in Chile by reducing the world price have clearly increased the long-run availability of copper worldwide.

Mineral Extraction and Incompatible Social Goods

Indigenous cultures, biodiversity, and pristine wilderness are all examples of social goods that many contend are simply incompatible with the extraction of mineral commodities. Where this is true, internalizing the costs of these social goods more than merely reduces the optimal output of mineral resources, it reduces it to zero. How then can society protect these goods without at the same time ensuring the long-run scarcity of mineral commodities?

As Chapter 6 noted, public policy has for years prohibited mineral production in certain areas, such as national parks and military reservations. Moreover, the total size of these areas has expanded greatly over the past several decades, while simultaneously the availability of many mineral commodities has increased. This suggests that the protection of social goods incompatible with mining is possible without necessarily causing scarcity, though clearly the more territory withdrawn from mineral extraction the greater the difficulties new technology faces in the struggle to keep mineral costs and prices from rising.

The challenge for public policy is not to choose between biodiversity, pristine wilderness, and indigenous culture on the one hand and the availability of mineral commodities on the other. It is not an either/or issue, a case of black or white, but rather a question of the appropriate tradeoff. How much biodiversity, wilderness, and indigenous culture does society want to preserve? As the amount increases, so does the price to society in terms of the long-run mineral availability sacrificed. At the same time, as the amount increases, the additional or marginal benefits to society will fall, assuming the most valuable sites for biodiversity, wilderness, and indigenous culture are selected for protection first.

This suggests that public policy should continue to preserve these social goods, and exclude mining from the areas required, up to the point where the marginal costs (in terms of the resource availability sacrificed) just equals the marginal benefits to society. Such a policy may or may not give rise to the scarcity of mineral commodities in the long run, but if it does, the policy still promotes the welfare of society as a whole.

Moreover, some economists and policy analysts (Krutilla and Fisher 1975, Dasgupta and others 1999) urge a cautionary policy, one that requires governments when weighing the benefits and costs to take account of the fact that once mining or other activities destroy such social goods, the damage is often irreversible. Moreover, as population and per capita income increase over time, the demand for these goods is likely to grow more rapidly than the demand for most other goods. Unlike other commodities, it is difficult or impossible to produce goods that consumers widely consider as close substitutes for biodiversity, indigenous cultures, and pristine wilderness.

Such concerns coupled with the vast quantities of marginal resources known to exist for many mineral commodities suggest that a prudent policy at least for the present would preclude mineral development wherever important social goods are threatened. For example, the troubled history of the Panguna mine on Bougainville Island in Papua New Guinea in retrospect indicates that the central government and private companies should have paid more attention to the concerns of the local people. Some might even argue that the mine should never have been developed, as it is simply too disruptive to the indigenous culture. Despite the attractive nature of this deposit, had this been the case, the effect on the long-run evolution of costs in the world copper industry would have been negligible. Indeed, given the large number of known but undeveloped porphyry deposits that could produce copper at costs close to many of today's operating mines, a number of mines could have been excluded from development with little effect on the long-run costs of producing copper.

Conservation, Recycling, and Renewable Resources

Concern over the long-run availability of mineral commodities has fostered, and continues to foster, widespread support for public policies and other activities that encourage conservation, recycling and secondary production, and where possible the greater use of renewable resources. Even if the long-run availability of mineral commodities is unknown, such policies, it is argued, are desirable as useful insurance in the event future shortages do arise.

Others contend that these activities—conservation, recycling, and increasing reliance on renewable resources—are inevitable. The world, they argue, is in the midst of what has to be a temporary period, as it exploits at an unprecedented rate its stocks of nonrenewable mineral resources. Once this era of profligate use draws to an end, as it must, there will be no choice. The world will have to rely far more on conservation, recycling, and renewable resources, and rising mineral commodity prices will provide the incentives to do so.

While both of these positions are at times advanced as self-evident and uncontroversial, they do raise a number of issues. The remainder of this section looks first at conservation, and then turns to recycling and the substitution of renewable resources.

Conservation

Conservation can be an elusive concept. To most people, it simply means using less. But this loose definition raises the question: how much less? At one extreme, which few conservationists would advocate and which in any case would garner little public support, conservation could mean doing completely without.

At the other extreme, conservation could mean using mineral commodities efficiently without needless waste. If mineral commodities are properly priced, then the marketplace should ensure they are used efficiency. In this case, no public policies or extra efforts to reduce mineral commodity use should be necessary. In practice, as Chapter 6 points out, prices for mineral commodities often do not include all the costs that their production and use impose on the environment and other social goods. In such cases, public policy is needed to ensure that these external costs are internalized. Here again, few are likely to object, at least in principle, to such efforts.

Conservation becomes more controversial when it entails reducing the use of mineral commodities below the levels that market efficiency dictates. Now society is paying a price for conservation in terms of less output and slower growth. As noted above, one might justify these costs as an insurance premium against the risk of future resource scarcity. This presumes, however, that more cost-effective methods of buying insurance do not exist. This may not be the case. The prospects for adequate future supplies might be enhanced much more by devoting the income that would be lost as a result of conservation to research and development.

Another possible reason for reducing current income to promote conservation rests on the belief that much of today's materialistic lifestyle in the rich countries is not only unnecessary but undesirable, particularly as it may increase the likelihood of future mineral shortages. Thus, a decline in income that discourages undesirable consumption can be accommodated at little or no cost to society as a whole.

Despite some intuitive appeal, this argument raises a number of difficult issues. First, how do we decide what are necessary and desirable expenditures, once individual preferences as expressed through the marketplace are rejected as appropriate indicators? Do we make such decisions collectively through the political process? If so, if current consumption patterns are truly perverse, why has public policy not already introduced luxury taxes or other measures sufficient to correct the situation? Second, once this issue is resolved and we identify which expenditures are unnecessary and undesirable, might it not be preferable to divert the resources used to produce them to other contemporary needs, such as housing, food, and medical care for the poor?

Third, as we have seen, natural capital in the form of mineral resources is just one of many assets the current generation will pass on, affecting the welfare of future generations. If we are concerned about intergenerational equity and the welfare of future generations, public policy should encourage the current generation to consume less and invest more. Investments might be made in education and human capital, in the strengthening of social and cultural institutions, or in the body of scientific knowledge and technology. Only under special conditions is the best investment likely to entail preserving mineral resources by conservation. Finally, as also noted before, it is not clear that equity is served by augmenting the welfare of future generations at the expense of the current generation, given the widespread poverty that currently afflicts large parts of the globe and the tendency over the past century in the developed countries for each succeeding generation to be better off than its predecessor.

Pulling together these various thoughts, we can make a strong case for conservation, when conservation means using mineral commodities efficiently up to the point where the costs (including all the social costs) of using another unit just equal the benefits to society. Moreover, so defined, the marketplace should encourage the efficient level of conservation as long as government policy forces producers and consumers to pay for all the costs. Over time, if scarcity drives the prices of mineral commodities up, conservation will cause their use to decline. Alternative, if scarcity should decline, allowing prices to fall, conservation so defined will dictate an increase in the optimal use of mineral commodities.

When conservation means something other than the efficient use of mineral commodities, as was the case, for example, with the Conservation Movement described in Chapter 2, it becomes more difficult to justify and more controversial.

Recycling and Secondary Production

Recycling and secondary production constitute an important source of supply for many metals, and are often perfect substitutes for primary output. So by increasing recycling, society can slow the rate at which primary mineral resources are exploited.

This does not mean, however, that all the metal in products coming to the end of their useful lives should be recycled. The lead once added to gasoline is still about, and in theory could be recycled. In such dissipated uses, however, scrap metal is prohibitively expensive to recycle.

What then is the optimal amount of recycling that society should undertake, and to what extent is government intervention in the marketplace needed to achieve this optimum? One position, which parallels the efficiency criterion for conservation, contends that the output of copper, lead, tin, or any other metal should be divided between primary and secondary production so that total production costs are minimized. This means continuing to recycle up to the point where the cost of obtaining one more ton of metal from recycling just equals the costs of producing one more ton from mining. Again, in both instances, the costs should include all costs, including the environmental costs.

Some scholars (Page 1977) who favor this view argue that public policy needs to encourage recycling since primary production gets more subsidies in various forms and imposes more external costs on society than secondary production. This is not easy to actually demonstrate, particularly in light of the many efforts over the past decade or two to promote recycling. However, to the extent public policy does discriminate in favor of primary production, a strong case can be made for eliminating this discrimination and thus for promoting more recycling.

Others contend that public policy should go further. Whether recycling is economic or not, they point out, often depends on the behavior of consumers. If the latter are conscientious and sort their waste, separating out, for example, metal cans, recycling becomes much more competitive. Educating consumers, like education in general, is a type of public good. By reducing the costs of recycling it provides benefits to society that at best recycling firms can capture only in part. Where such external benefits exist, markets will fail, providing less of a good or service than is optimal from the point of view of society. This, of course, is the primary rationale for government support for research and development and for education. As a result, the argument goes, the government has a legitimate role to play in encouraging consumer behavior that promotes recycling.

The same rationale can be employed to justify government support for research and development that reduces the cost of recycling and so promotes secondary production. Here, however, the argument of market failure supports government support for research and development that reduces the costs of primary production as well. So whether optimal public support for research and development would favor secondary or primary production is unclear.

Perhaps the most common and problematic case for policies favoring recycling contends that secondary production buys society time. According to this argument, as the world moves, as it must, from a cowboy economy based on nonrenewable resources to a spaceship economy based on renewable resources and secondary production, secondary production slows depletion. This extends the period available for the world to navigate this difficult transition period, and reduces the resulting dislocation and hardship.

We have seen, however, that depletion is not a question of the physical availability of mineral resources, but rather of costs. Should depletion eventually drive the costs of primary production up greatly, then the world will have to make the transition from nonrenewable primary resources to renewable resources and secondary production. However, forcing society to incur these costs now can be questioned for at least two reasons. First, while primary mineral commodities may become scarce in the long run, this is not certain. Why pay to alleviate a problem that may not arise? Why not pay when and if the problem actually occurs?

Second, even if scarcity were certain, the income lost by pushing recycling beyond the point that minimizes the total production costs for mineral commodities might be better spent in other ways. Promoting technologies that reduce the costs of finding and producing mineral commodities or that develop suitable alternatives, for example, may be a far more effective strategy for mitigating the impact of depletion. More generally, investing these funds by attacking poverty, strengthening institutions, reducing corruption, and enhancing political stability may, as we have seen, pay far greater dividends to future generations, as compensation for our possible failure to maintain the long-run availability of mineral commodities.

The above, it is important to note, does not necessarily preclude public support for recycling. It does imply, however, that the case for such support is not self-evident, but rather requires empirical verification.

Renewable Resources

Solar power, biomass, and other renewable resources are replenishable on a time scale of relevance to humanity, and so can be used indefinitely. Does this mean, as is sometimes argued, that society should where feasible promote the use of renewable in place of nonrenewable resources?

The answer to this question closely parallels the preceding discussions of conservation and recycling. A strong case for market failure and government intervention favoring renewable over nonrenewable resources exists if the production and use of nonrenewable resources imposes greater external costs, or in other ways receives subsidies that exceed those bestowed on the production and use of renewable resources. Of course, should careful analyses of the relative subsidies document that renewable resources are actually favored, then government policy should tilt in the opposite direction.

Government policies that favor the use of renewable resources beyond such measures are more difficult to justify, since they reduce income and wealth. This cost helps mitigate a problem that may in the end not arise. In addition, the income and wealth given up by the current generation might if spent in others ways enhance the welfare of future generations even more.

This seems particularly so since renewable resources can also suffer from depletion if use exceeds sustainable levels. A cursory glance at the resources generating the greatest concerns at the beginning of the 21st century finds the focus largely on renewable resources—climate, the ozone layer, water, air, soils, whales, and biodiversity in general. The general perception that renewable resources are sustainable while nonrenewable resources are not is clearly incorrect. Indeed, with renewable resources physical exhaustion is in some instances a real threat, as the extinction of many animal species over the past century illustrates. This raises the possibility that the distinction between renewable and nonrenewable resources is misleading. Both can suffer from depletion, and in the case of renewable resources depletion may entail more than just rising costs.

Population, Poverty, and Discrimination

This final section explores the fascinating relationship between the long-run availability of mineral commodities and the world's population. In particular, it focuses on two issues. The first concerns the influence of resource availability on population, and addresses the question: To what extent does the availability of mineral commodities impose an upper limit or ceiling on the world's population? The second examines the influence of population on resource availability, and considers the question: Is a growing population a threat to the long-run availability of mineral commodities?

The Population Ceiling

At any particular time, available world resources do impose an upper limit on the number of people the world can support. Malthus and other Classical economists, as we saw in Chapter 2, recognized this fact over two hundred years ago. According to the law of diminishing returns, as more of a variable input (people) is added to a fixed input (land or resources in general), the additional return or output from adding one more unit of the variable input must at some point decline. Eventually, this decline will push the average output per person down until it just equals the subsistence level. At this point, which

Malthus recognized was not a pleasant situation, the world reaches the upper limit on the number of people it can sustain.

Several aspects of this scenario, however, deserve further consideration. First, for most people the optimal population level is significantly below the maximum possible. There are many reasons for this, including the fact that a world where everyone just barely manages to survive is not particularly enticing.

Second, it is clear the world possesses sufficient supplies of mineral commodities to support its current population of six billion plus people, and probably can support the nine to ten billion people expected by the middle of this century when current forecasts see the world's population peaking. Less clear is how far the developing countries can move toward the high living standards currently prevailing in the developed countries in light of these population figures and the long-run availability of mineral commodities. This, however, is a concern more relevant to the optimum level of population, than the ceiling. Moreover, while economic development is still poorly understood and appears to depend on the fortunate confluence of many factors, the long-run availability of mineral commodities does not appear to be of great importance. Korea, Hong Kong, Singapore, Malaysia, Chile, and more recently China have all enjoyed rapid rates of economic growth over the past several decades, while many other developing countries have not, even though in a growing global economy all have more or less equal access to needed mineral commodities.

Third, renewable as well as nonrenewable resources impose a ceiling on population. Indeed, the availability of land, water, and other renewable resources may well constrain population growth long before nonrenewable resources, the latter's finite nature notwithstanding. If so, the mineral constraint on population is non-binding, and hence largely or totally irrelevant.

Fourth, the population ceiling arising from mineral commodities is not stationary but rather shifts over time responding to changes in their long-run availability. If new technology continues to offset the cost-increasing effects of depletion, the population ceiling could rise indefinitely. Growing scarcity would have the opposite effect.

So the answer to the first question is: Yes, the availability of mineral commodities does impose a limit on the world's population. Though true, and of some interest, this fact has limited significance in practice, in part because the ceiling is constantly changing, in part because renewable resources may dictate an even lower population limit, in part because the ceiling is above the current level of population and above those levels likely to prevail over the foreseeable future, and most importantly because the desired or optimum level of population is far below the ceiling and set largely by other considerations.

The Population Threat

This brings us to the second question: Is population growth a significant threat to the long-run availability of mineral commodities? Here again the conventional wisdom, that the answer to this question is yes, is at best only partially correct. It is true that an increase in population, everything else remaining the same, tends to increase the demand for mineral commodities and so drives society up its cumulative supply curve at a faster pace than would otherwise be the case. However, as Julian Simon has so persistently argued, people influence the supply as well as the demand for mineral commodities. The more people, the more minds to develop the innovations and new technologies that shift the cumulative supply curve down over time. Whether more people on balance promotes or impedes the long-run availability of mineral commodities is an open question requiring empirical evidence for its resolution. Simon contends that a growing population thanks to the ingenuity and resourcefulness of people increases availability; others are less sanguine.

While controlled experiments of the kind so common in physics, chemistry, and other natural sciences are difficult to replicate in the social sciences, the past century does in a way provide a laboratory for an empirical test. Between 1900 and 2000 world population more than tripled, rising from under two billion to over six billion. Yet according to the measures reviewed earlier, resource availability did not significantly decline. This provides little support for the hypothesis that population growth seriously threatens the long-run availability of mineral commodities. While the future could be a different story, those who advocate slowing population growth in order to preserve the long-run availability of mineral commodities need at least to ponder the possibility that they may unwittingly be pushing counterproductive policies.

The influence that people have on the supply of mineral commodities via their ingenuity and influence raises some other intriguing and even paradoxical issues. Poverty and discrimination, for instance may be a far more serious challenge to the availability of mineral commodities than population per se. The United Nations (2001) estimates that poverty afflicts one in four people living in the developing world, or some 1.2 billion individuals, where poverty means living on less than one dollar a day. Without adequate housing, food, health care, and education, these individuals simply do not have the opportunity to develop the skills and talents needed to promote the technologies that push the cumulative supply curve down over time, or to contribute back to society in other ways.

This reflects a loss that makes the entire world, developed as well as developing, poorer than it otherwise would be. How many Leonardo DaVincis, Thomas Edisons, and Albert Einsteins have lived and died in the slums of Calcutta, Rio de Janeiro, and New York lacking the means to develop their extraordinary talents? How much better off would the world in general be without poverty, and how much more available would mineral commodities be in particular?

Discrimination poses an equally troubling problem. Around the world, women and minorities are denied opportunities to obtain the education and experience needed to pursue productive professional careers. Like poverty, discrimination affects us all, not just those afflicted. Like poverty, it does so in a particularly insidious way, by preventing what might have been. As a result, those who are not directly affected have little or no idea of the magnitude of the losses they suffer. Indeed, many are unaware that poverty and discrimination impoverishes them too.

While there is no way to assess accurately these costs, they must be huge. Between a third and a fourth of humanity currently is unable to contribute to the welfare of society as a result of poverty and discrimination. If these or higher figures apply to the past as well, not an unreasonable assumption, they suggest that the benefits the world enjoys from the stock of existing technology (to say nothing of the those flowing from the arts and humanities) might now be 20 to 40 percent greater. In the case of mineral commodities, such an additional infusion of new technology would have accentuated the tendency over the past century toward increasing availability, and enhanced the prospects for the continuation of this favorable trend in the future.

These issues suggest that the frequent accusations leveled by many against the developed countries, and in particular against the United States, that their profligate use of mineral commodities is inequitable and unjust may be misguided. While the per capita consumption of mineral commodities in India, Nigeria, China, and other developing countries is quite low, the widespread poverty in these countries means they can contribute only modestly to the on-going struggle to offset the cost-increasing effects of depletion. The developed countries on the other hand, despite their apparent profligate use, are in a far stronger position to foster the long-run availability of mineral commodities. If profligate use helps generate the income that supports the development of new cost-reducing technologies, it may actually benefit the developing countries despite the claims to the contrary.

Some may find this idea disturbing. They can, perhaps, take comfort in the fact that its underlying logic also leads to the conclusion that the developed countries should help fight poverty and discrimination around the world, not out of charity, or at least not solely out of charity, but because it is also in their own self interest to do so.

Of course, discrimination, poverty, and population growth may not be independent. In particular, population growth may contribute to poverty. Where this is so, the case for limiting population growth as a means of promoting the future availability of mineral commodities is easier to make. Where population growth does not aggravate poverty, however, if is far less clear that mineral commodity availability is a valid justification for curbing population growth.

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